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AIR MINISTRY

METEOROLOGICAL RESEARCH COMMITTEE

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Further observations of humidity up to 50,000 feet made from aircraft of the Meteorological Research Flight in 1955

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Summary

The humidity of the air up to about 50,000 feet was measured on 46 occasions during 1955 using a pressurised Dobson-Brewer frost point hygrometer installed in the Canberra aircraft of the Meteorological Research Flight. The resulting observations are presented and a comparison and combination of them is made with the observations for 1954 described in (2) and (3).

Introduction

Measurements of humidity in the upper troposphere and lower stratosphere are discussed in (1) and (2). The Canberra aircraft was first used to obtain flights to about 50,000 feet in 1953. Regular observations began in 1954 and the results are discussed by Murgatroyd, Goldsmith and Hollings (3). The present report discusses measurements made in 1955 by similar methods.

Instrumentation

As stated in ref. (2), the pressurised Dobson-Brewer frost point hygrometer is installed on the starboard side of the Canberra aircraft and frost points were obtained using this instrument. At 50,000 feet the expected frost point is near -120°F. and glassy ice deposits which form at these temperatures are very difficult to see: but the observers (J.K. Mackenzie and M.J. Kerley) were able to make readings near this level with spans of only 8 to 12°F. between observations of deposit increasing and deposit decreasing. Only one or two frost points were obtained by the method described in ref. (5), using compressed air from the Avon engine of the Canberra aircraft, mainly because there was little difficulty in measuring them directly at the values encountered. Temperature was measured by a standard flat plate aircraft thermometer using a Balanced Bridge Mark II, and altitude and airspeed were taken from the aircraft instruments available on the navigator's console.

Observations

The 46 observations are shown in Table I and Fig.1 shows the arithmetic mean of the ascents taken only at levels where the number of observations was sufficient to justify the averaging process. These flights can be divided into two classes

(1) ascents made before 26 October, 1955

(2) ascents made after 26 October, 1955.

In the first class, the area covered by the ascents was considerable since

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in each flight lasting two hours the aircraft travelled about 1,000 miles and consecutive readings in the vertical were not over the same point on the ground. In the second class however the area covered by the aircraft was much reduced since an attempt was made to remain within a 30 mile radius of a radio-sonde station. In either class, of course, the individual values of frost point are means over some 20-30 miles, which is about the distance travelled by the aircraft while the observation is being made. The timing of these ascents was designed to coincide with the ascent of the radio-sonde balloon, and a comparison of the aircraft ascents and the balloon ascents will be the subject of a later report. I.C.A.N. heights measured by aircraft altimeter have a standard error of about 200 feet while the frost point is measured to within a standard error of 3°F. at maximum altitude and considerably better at lower levels. Air temperature is computed from the indicated temperature of the flat plate thermometer using a correction for airspeed and height. The speed correction coefficient is assumed constant at 1.76 and the temperature is estimated to be correct to 2°F. at 20,000 feet and 4°F. at 48,000 feet (standard errors) (4).

Discussion

Fig.2 shows the mean temperature and frost point referred to the tropopause level. "High tropopauses" are defined as in ref.(3) and are those at 36,000 feet and above. "Low tropopauses" are cases where the tropopause is 35,000 feet or below. 35,000 feet is very near the mean height of the tropopause for the ascents made in 1955. The mean frost points shown in Fig.2 decrease with height above the tropopause and at 15,000 feet above this level tend to reach a constant value: the lapse of frost point is 4.4°F. in the 1,000 feet above the tropopause but only .7°F. per thousand feet at 10,000 feet above a high tropopause, while at 10,000 feet above a low tropopause it is 2.6°F. per thousand feet.

In Fig.1 it can be seen that the mean frost point decreases almost linearly to 40,000 feet but changes its slope above this level so that at 50,000 feet the value of -117°F. is approached. The mean temperature shows an almost isothermal layer between 35,000 feet and 40,000 feet and then increases to another isothermal layer above 45,000 feet.

In Fig.2 the mean values show that for high tropopauses the frost points are generally lower than for a low tropopause.

The period of these ascents can be divided into two distinct seasons:-

(1) February and March -with late winter and early spring ascents.

(2) October and November -with early winter and late autumn ascents.

It is not therefore possible to claim that the observations are representative of conditions throughout the year, as in ref.(3) and it may be noted here that the mean temperature and mean frost point obtained and shown in Table II are several degrees below the comparable values for 1954 with the exception of the frost points at 44,000 and 48,000 feet (the latter exception is discussed below).

The high frost point measured on the 9th March 1955 is the subject of a separate article by Mr. J.K. Mackenzie (ref. (6)).

Fig.3 shows the variation of frost point at the tropopause and at 10,000 feet above the tropopause with season. This figure suggests that day to day variations of temperature, frost point and height of the tropopause are more significant than seasonal trends - a feature confirming the suggestions in ref.(2).

/Combination

Combination and comparison of observations for 1954 and 1955

Fig.4 shows mean curves of frost point and temperature at selected levels using observations for 1954 and 1955 combined. As stated in the foregoing discussion the 1955 observations were made in only restricted periods of the year but in 1954 observations were made in most months and were more uniformly spaced.

Table II

Mean values of temperature °F. and frost point for selected levels with standard deviations for 1954 and 1955

Height ft.	Mean temperature °F. 1954 & 1955	1955	1954	Standard deviation	Mean frost point °F. 1954 & 1955	1955	1954	Standard deviation
20,000	-14.4	-18.2	-7.7	10	-35	-38	-32	17
25,000	-35.2	-37.6	-30.2	8	-54	-56	-50	14
30,000	-53.3	-57	-48	7	-70	-74	-65	11
34,000	-66.9	-67.9	-64	7	-84	-86	-79	10
36,000	-68.9	-71.8	-64.5	10	-90	-92	-87	9
40,000	-67.4	-72.6	-60.8	15	-104	-105	-103	8
44,000	-64.2	-67.2	-60.3	9	-113	-112	-113	6
48,000	-63.5	-68.2	-58.4	9	-116	-115	-116	7

Table II compares mean values for selected levels for the two years. One interesting feature of Table II is that although there can be a spread of 10°F. in the mean at some levels the frost point at 48,000 feet and at 40,000 feet shows little variation in the mean from year to year. One disconcerting feature of these tables is the high standard deviation of frost point from the mean at 48,000 feet, and this deserves further discussion.

Fig.5 shows the total number of observations of frost point at 48,000 feet arranged in steps of 1°F. It will be seen that they are grouped fairly symmetrically about a temperature of -117°F., but that three observations, -102, -91, -89°F., appear to be anomalous. Two of these (-91 and -102°F.) occurred on consecutive days and Mackenzie (6) has suggested that they may be the effect of a nuclear explosion. If this view is accepted, and the three very high values are rejected as being due to unnatural causes, a mean frost point at 48,000 feet of -116.8°F. is obtained, with a standard deviation of 3.2°F.

A comparison of tropopause height with frost point at 48,000 feet has been made and Table III shows this comparison. The probability that the frost point is below the mean value for both years when the tropopause is high seems reasonably well established from this.

/Table III

Table III

Variation of frost point at 48,000 feet with tropopause height

	All frost points			Three high frost points omitted		
	Number of observations			Number of observations		
Tropopause	Above mean	Below mean	Total cases	Above mean	Below mean	Total cases
High	10	25	35	9	24	33
Low	12	14	26	11	14	25
	Probability		Total probability	Probability		Total probability
High	0.29	0.71	1	0.27	0.73	1
Low	0.46	0.54	1	0.44	0.56	1

Conclusion

These observations generally confirm the conclusions of ref.(2). There now seems little case for continuation of the humidity measurements to 50,000 feet over Southern England as a separate investigation although further data can be obtained incidentally during other investigations, e.g., measurements of ozone, radiation etc.

It is suggested that further work on humidity measurement at high levels should now be extended to other latitudes and greater heights. Only a small increase of the latter is possible with present aircraft and the acquisition of a suitable machine of greater performance is extremely desirable. It should however be possible to use facilities now available to R.A.E. at Farnborough to make measurements in other latitudes in the near future if this is considered worthwhile.

References

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(2) Murgatroyd, R.J., Goldsmith, P. and Hollings, W.E.H. Meteorological Research Papers, Air Ministry, London, No.877, 1954.

(3) Murgatroyd, R.J., Goldsmith, P. and Hollings, W.E.H. Quart. Journal Royal Met.Soc., Volume 8,No.350,p.533, October,1955.

(4) Durbin, W.G. Meteorological Research Papers, Air Ministry, London, No.930, 1955.

(5) Goldsmith, P. Meteorological Research Papers, Air Ministry, London, No.859, 1954.

(6) Mackenzie, J.K. Met. Mag., London, Vol. 86, No. 1010, 1956.

Table I

High level ascents 1955

Air temperature and frost point (in brackets)

* Height of tropopause

Date		3 Feb.	4 Feb.	7 Feb.	p.m. 8 Feb.	a.m. 8 Feb.	9 Feb.	10 Feb.	11 Feb.	14 Feb.	15 Feb.	16 Feb.	28 Feb.	1 Mar.	2 Mar.	3 Mar.	4 Mar.	9 Mar.	10 Mar.	10 Mar.	11 Mar.	14 Mar.	15 Mar.
Time G.M.T.		1350	1220	1505	1410	1015	0950	1020	1050	1140	1205	1155	1205	1345	1055	1130	1125	1615	1140	1620	1205	1150	1150
Height (ft.)	Mb.																						
5,000	843	+24.3 (6000') (+08)	+28.7 (+16)	+37.4 (+33)				+22.6 (+10)	+14.0 (+08)	+20.0 (+16)	+18.0	+24.7 (+07)	+28.8			+38.0		+11.1					
7,000	782						+17.0																
10,000	697	+7.8 (-23)	+11.9 (-17)	+23.8 (+06)	+15.7 (-33)	+18.5 (-04)	+15.0 (0)	+1.8 (-25)	+0.8 (-49)	+10.9 (-55)	+07.5	+6.6 (-08)	+18.9			+23.2	+21.5	+4.0					
15,000	572	-12.2 (-40)	-4.4 (-22)	+04.5 (-30)	+03.8 (-09)	+07.8) (+01)	-8.8 (-18.0)	-21.2 (-41)	-15.2 (-26)		-09.4	-0.9 (-40)	+1.5			+08.3 (-16)		-12.7					
20,000	466	-33.2 (-60)	-23.7 (-37)	-07.7 (-17)		-09.4 (-23)	-24.1 (-59.0)	-38.4 (-58)	-35.4 (-44)		-30.3	-24.5 (-51)	-08.4 (-18)			-12.5 (-33)	-14.7	-26.2	-22.3			-12.7	
25,000	376	-43.1 (-79)	-45.6 (-61)	-30.4 (-46)	-33.0 -(40)	-30.3 (-46)	-43.0 (-84)	-45.2 (-84)	-57.8 (-72)	-46.4 (-49)	-46.2	-42.1 (-70)	-28.5 (-37)			-36.4 (-55)	-39.6	-46.4	-42.2		-36.4	-33.7	
26,000	360																	-51.5			-41.0	-40.3	
27,000	344																	-55.3			-46.1	-45.0	
28,000	329																	-58.7			-50.5	-49.5	-53.2 (-58)
29,000	315																-55.7 (-69)	-61.4			-54.1		-53.5 (-62)
30,000	301	-55.0* (-94)	-61.6 (-82)	-52.3 (-66)	-52.4 (-68)	-53.8 (-73)	-61.2 (-82)	-51.2 (-96)	-61.7* (-93)	-63.2 (-81)	-59.7 (-78)	-61.4 (-81)	-52.9 (-68)	-54.2 (-60)	-56.9 (-69)	-59.4 (-73)	-61.0 (-70)	-64.0 (-73.0)	-62.8 (-70)		-60.5 (-70)	-59.0 (65)	-61.3 (-70)
31,000	287																	-66.2 (-79.0)	-66.6		-62.5 (-69)	-61.0	
32,000	274					-64.0 (-75)		-56.9* (-103)		-68.6* (-91)		-63.7 (-90)			-67.3		-70.3 (-76)	-70.5* (-75)	-68.9		-68.4	-66.0 (-75)	-68.8 (-77)
33,000	262	-55.3																	-71.5				
34,000	249.8				-68.7 (-77)	-71.0 (-75)		-53.3 (-106)	-60.5 (-102)	-70.2 (-93)		-67.2* (-95)					-76.5 (-81)	-68.0 (-83)	-73.8		-75.1	-72.5 (-84)	-77.5 (-81)
35,000	238	-49.5 (-100)	-65.3* (-100)	-72.9* (-77)			-65.2* (-96)				-68.5* (-103)		-75.6 (-77)	-77.4 (-80)	-80.2 (-89)	-73.1 (-92)			-74.9 (-88)		-79.6		
36,000	227	-50.5 (-108)				-79.7 (-79)		-56.9 (-108)		-70.0 (-99)		-64.5 (-101)					-81.3 (-89)	-71.5 (-84)	-77.6		-83.3 (-89)	-81.3 (-88)	-84.9 (-90)
37,000	216																		-78.1*		-85.6*	-83.8	
38,000	206	-48.8 (-113)			-76.0* (-96)	-82.1* (-92)	-63.7 (-107)	-58.1 (-110)	-59.5 (-110)	-70.7 (-101)		-64.3 (-106)			-90.4 (-98)		-90.8* (-97)	-67.3 (-90)	-74.7		-83.5	-89.8 (-100)	-88.2 (-94)
39,000	197																		-76.2		-83.5		
40,000	187	-51.5 (-115)	-54.6 (-113)	-73.9	-72.0 (-112)	-77.4 (-106)	-59.9 (-110)	-59.7 (-110)	-57.6 (-111)	-69.7 (-105)	-60.5 (-114)	-64.8 (-114)	-87.3* (-97)	-92.4* (-101)	-94.3* (-100)	-88.3* (-100)	-85.8 (-99)	-65.7 (-93.0)	-75.9 (-98)	-76.6 (-99)	-85.8	-97.7* (-106)	-91.5* (-97)
41,000	179																		-75.1		-84.2	-97.7	
42,000	170	-53.5	-59.3 (-117)		-66.4 (-115)	-70.0 (-115)	-58.4 (-111)	-55.0 (-115)	-59.8 (-112)	-63.4 (-108)	-64.4 (-114)	-55.3 (-115)			-85.2 (-112)		-81.8 (-108)	-65.9 (-90)	-70.4	-71.3 (-103)	-83.8	-93.7 (-108)	-85.5 (-112)
43,000	162																				-78.2	-86.0	
44,000	155	-52.2	-57.5 (-116)		-66.0 (-117)	-72.5 (-115)	-61.1 (-111)	-57.7 (-117)	-60.8 (-113)	-60.4 (-109)	-65.2 (-115)	-57.4 (-117)			-80.9 (-113)		-75.3 (-113)	-65.2 (-89)	-73.6 (-106)	-70.9 (-108)	-74.4	-82.6 (-114)	
45,000	147												-77.9 (-116)	-78.8 (-118)		-78.4 (-114)			-68.8		-72.0	-80.2	
46,000	140	-55.8	-57.0 (-114)		-70.7 (-118)	-75.9 (-117)	-65.7 (-113)	-59.0 (-119)	-62.5 (-114)	-58.7 (-109)	-62.5 (-116)	-61.9 (-118)			-77.0 (-116)		-75.7 (-114)	-61.6 (-92)	-69.3	-70.7 (-111)	-70.0	-75.7 (-119)	
47,000	133																		-66.9		-69.6		
48,000	127	-56.3	-55.6		-66.3 (-118)	-68.7 (-118)	-64.5 (-114)	-63.2 (-119)	-63.5 (-117)	-60.9 (-112)	-63.7 (-116)	-71.6 (-119)	-79.1 (-118)		-76.7 (-117)			-63.8 (-91)	-71.8 (-102)	-67.9 (-111)	-70.4 (-117)	-77.2 (-119)	
49,000	121											-64.9 (-120)			-74.4 (-118)								
50,000	116	-62.0	-58.1		-66.5 (-119)		-64.7	-65.2 (-118)	-63.5 (-118)	-62.8	-61.9 (-118)												
tropopause height		30,000	35,000	35,000	38,000	38,000	35,000	32,000	30,000	32,000	35,000	34,000	40,000	40,000	40,000	40,000	38,000	32,000	37,000	-	37,000	40,000	40,000

Table I (contd.)

* Height of tropopause

Date		16 Mar.	18 Mar.	18 Mar.	21 Mar.	28 Mar.	30 Aug.	31 Aug.	29 Sept.	4 Oct.	12 Oct.	17 Oct.	18 Oct.	18 Oct.	20 Oct.	26 Oct.	28 Oct.	31 Oct.	1 Nov.	8 Nov.	11 Nov.
Time G.M.T.		1525	1145	1605	1115	1510	1025	1025	1445	0805	1440	1045	1045	1510	1445	1530	1345	1345	1350	1000	11130
Height (ft.)	Mb.																				
5,000	843			+18.5 (+15)	+21.2 (-01)		(+37)	+49.5 (+26)				+25.1 (+18)			+37.8	+38.4	+29.0 (+5)	+29.5 (-20)	+32.7 (-22)	+41.3 (+33)	
7,000	782																				
10,000	697			+13.3 (-11)	+11.7 (-14)		+33.8 (+16)	+27.4 (+19)			+28.5 (+14)	+13.6 (-22)	+9.5 (-25)		+20.0 (+18)	+29.3	+09.1 (-14)	+20.1 (00)	+18.5 (-06)	+21.8 (+19)	+25.0
15,000	572		-4.0	-3.3 (-20)	-1.6 (-4)		+18.7 (-13)	+9.2 (+01)			+13.5 (-06)				+03.0 (-09)	+10.9	-04.0 (-56)	+1.5 (-16)	+02.1 (-12)	+04.9 (-12)	+7.2
20,000	466		-21.0	-23.5 (-53)	-20.3 (-49)	-28.0 (-66)	-0.8 (-23)	-4.8 (-26)			-06.2 (-09)	-13.0	-21.5 (-23)	-16.3 (-27)	-21.3 (-28)	-11.2	-17.8 (-53)	-15.1 (-27)	-19.1 (-27)	-16.3 (-54)	-12.5
25,000	376		-42.4	-43.6 (-67)	-39.9 (-70)	-46.1 (-49)	-23.5 (-26)	-26.0 (-61)	-17.0 (-37)		-25.1	-41.2	-42.4 (-44)	-39.4 (-57)	-36.3 (-62)	-28.3	-40.8 (-66)	-36.9 (-54)	-41.0 (-54)	-40.5 (-51)	-33.0 (-43)
26,000	360		-46.9										-46.2	-44.4				-41.3	-45.1	-42.6	
27,000	344		-51.9			-53.3 (-67)							-50.5	-43.8 (-59)				-45.6	-47.9 (-63)	-47.2 (-50)	
28,000	329		-55.8 (-68)			-56.8 (-67)					-39.9 (-44)		-53.8 (-56)	-53.9		-41.4 (-56)		-51.3	-49.7	-51.5	
29,000	315	-57.8 (-56)	-60.2 (-72)										-58.2	-58.8 (-63)		-45.3		-54.1	-56.1	-54.5	-53.7 (-63)
30,000	301	-64.4 (-62)	-64.0 (-73)	-62.7 (-77)	-60.9 (-81)	-66.5 (-71)	-42.6 (-74)	-47.2 (-67)	-39.1 (-59)	-55.6 (-75)	-48.3 (-52)	-54.0	-65.0* (-67)	-62.8	-55.8 (-72)	-48.0 (-62)	-59.7 (-77)	-58.9 (-71)	-60.9 (-81)	-60.6 (-72)	
31,000	287	-66.0	-65.8 (-79)				-46.0	-52.2			-52.4	-60.7	-65.6	-67.9* (-72)	-59.7*	-54.5	-62.3*	-63.7	-64.9	-63.3	
32,000	274	-70.4	-69.2 (-85)	-70.0* (-83)	-67.7 (-85)	-73.2* (-77)	-50.5 (-78)	-56.0 (-77)	-49.0 (-69)	-61.8 (-78)	-57.1 (-62)	-65.2 (-74)	-68.1 (-84)	-68.5	-59.1 (-80)	-60.1 (-62)	-63.0 (-88)	-67.0	-68.0	-66.8	
33,000	262	-75.2 (-82)					-54.0	-60.9			-60.6	-69.0	-68.4		-56.6	-63.3	-63.3	-71.1 (-84)	-71.1	-70.7* (-74)	
34,000	249.8	-79.0 (-85)	-73.9 (-92)	-72.4 (-92)	-74.8* (-91)	-68.6 (-93)	-58.8 (-83)	-63.1* (-77)	-57.3 (-70)	-67.4* (-81)	-63.8 (-73)	-68.9 (-85)	-68.1 (-92)	-67.9 (-93)	-51.3 (-95)	-68.4 (-73)	-65.1 (-92)	-74.4	-72.0 (-85)	-70.4	
35,000	238		-75.4				-60.5	-63.1	-59.2		-67.9	-74.3*	-66.1		-48.3	-72.9	-68.5	-78.9	-74.1*	-69.5	-82.3 (-86)
36,000	227	-85.0 (-91)	-78.7* (-95)	-78.0 (-95)	-76.2 (-96)		-63.5 (-84)	-61.7 (-92)	-65.0 (-75)		-68.2 (-86)	-70.2 (-93)	-64.9 (-103)	-71.1 (-97)	-46.3 (-102)	-75.8 (-84)	-70.1 (-95)	-82.5 (-90)	-74.2	-68.6 (-94)	-78.5 (-86)
37,000	216						-66.2*	-63.2	-69.9		-69.0	-70.8	-62.2		-50.8		-71.1	-84.5*	-72.4	-69.2	-86.9* (-88)
38,000	206	-89.8* (-93)	-76.2 (-101)	-75.4 (-99)	-71.8 (-107)		-65.3 (-97)	-60.7 (-102)	-73.3 (-87)		-72.0 (-83)	-72.0 (-99)	-61.7 (-107)	-65.7 (-107)	-48.4 (-105)	-83.9* (-88)	-68.9 (-101)	-84.8 (-90)	-70.7 (-103)	-66.4 (-101)	-77.8 (-95)
39,000	197		-73.9				-60.8	-60.3	-76.4		-77.1*	-69.5	-60.1		-47.9 (-106)		-70.2	-78.4		-66.7	-73.5 (-104)
40,000	187	-89.1 (-97)	-71.8 (-109)	-80.3 (-103)	-66.8 (-113)		-65.5 (-103)	-60.2 (-108)	-80.3 (-88)	-65.2 (-103)	-74.6 (-101)	-64.2 (-104)	-57.8 (-110)	-61.2 (-111)	-51.4 (-108)		-66.7 (-105)	-82.9 (-101)		-65.7 (-107)	-66.4 (-106)
41,000	179								-83.5		-71.8					-75.8					
42,000	170			-73.3 (-113)	-64.3 (-114)		-60.2 (-109)	-60.0 (-111)	-84.2* (-95)		-73.9	-65.7 (-108)		60.8 (-111)	-55.5 (-109		-61.4 (-112)		-70.6 (-109)		
43,000	162								-82.3		-74.0			-63.2				-72.9 (-113)		-63.9 (-112)	
44,000	155			-76.5 (-116)	-63.0 (-116)		-59.0 (-114)	-62.7 (-116)	-81.6 (-107)	-66.6 (-114)	-72.0	-65.6 (-112)		-60.3 (-112)	-56.8 (-109)		-66.8 (-115)		-70.5 (-112)		
45,000	147										-71.5			-62.0							
46,000	140			-70.0 (-116)	-61.3 (-117)		-65.8 (-117)	-63.2 (-118)	-86.5 (-111)	-63.8				-62.0 (-114)	-56.4 (-111)		-68.1 (-116)	-72.7 (-113)	-71.0 (-114)	-64.0 (-113)	
47,000	133													-63.5							
48,000	127			-70.0 (-118)	-62.0 (-117)		-65.8 (-117)	-59.2 (-118)	-87.3 (-115)	-66.9 (-118)				-63.9 (-114)	-62.8 (-112)		-65.7 (-117)	-72.3 (-116)	-68.9 (-116)	-66.4 (-115)	
49,000	121																				
50,000	116																				
tropopause height		38,000	36,000	32,000	34,000	32,000	37,000	34,000	42,000	34,000	39,000	35,000	30,000	31,000	31,000	38,000	31,000	37,000	35,000	33,000	37,000

Table I (contd.)

High level ascents 1955

Air temperature and frost point (in brackets)

*Height of tropopause

Date		22 Nov.	28 Nov.	29 Nov.	1 Dec.
Time G.M.T.		1335	1335	1335	1125
Height (ft.)	Mb.				
5,000	843	+27.5		+38.4	
7,000	782				
10,000	697	+14.5 (-13)	+26.0	+24.8	
15,000	572	+04.2 (-46)	+07.9	+05.8	
20,000	466	-17.9 (-36)	-13.5	-13.6	-19.5
25,000	376	-33.0 (-59)	-34.7	-27.0	-42.0
26,000	360			-36.1 (-84)	
27,000	344			-46.9	
28,000	329		-50.8	-49.9 (-70)	-51.2 (-81)
29,000	315		-53.9	-48.7	-57.7 (-57)
30,000	301	-50.1 (-77)	-58.9	-49.7 (-82)	-55.6 (-88)
31,000	287	-53.0	-63.2	-54.8	
32,000	274	-57.2	-66.1	-58.2 (-88)	-60.0 (-88)
33,000	262	-59.8	-70.9 (-79)		-61.5* (-92)
34,000	249.8	-63.7		-64.1 (-90)	-60.8
35,000	238	-67.7 (-91)			-60.8
36,000	227	-72.8*	-79.6* (-85)	-77.3	-60.5 (-99)
37,000	216	-73.9	-79.6		-62.2
38,000	206	-74.2	-79.3	-71.7* (-95)	-61.2
39,000	197	-75.8	-79.0		-66.3
40,000	187	-75.4 (-103)	-78.6 (-99)	-83.4	-65.4 (-111)
41,000	179		-76.8		-64.4
42,000	170	-77.6	-75.5 (-110)	-74.1 (-112)	-65.4
43,000	162				-64.1
44,000	155	-77.4 (-112)		-73.7	-67.0 (-114)
45,000	147				-66.8
46,000	140	-78.8	-73.8 (-114)	-75.6 (-116)	-68.2
47,000	133				-68.3
48,000	127	-79.4 (-115)	-74.2 (-117)	-76.0 (-117)	-69.9 (-120)
49,000	121				
50,000	116				
tropopause height		36,000	36,000	38,000	33,000

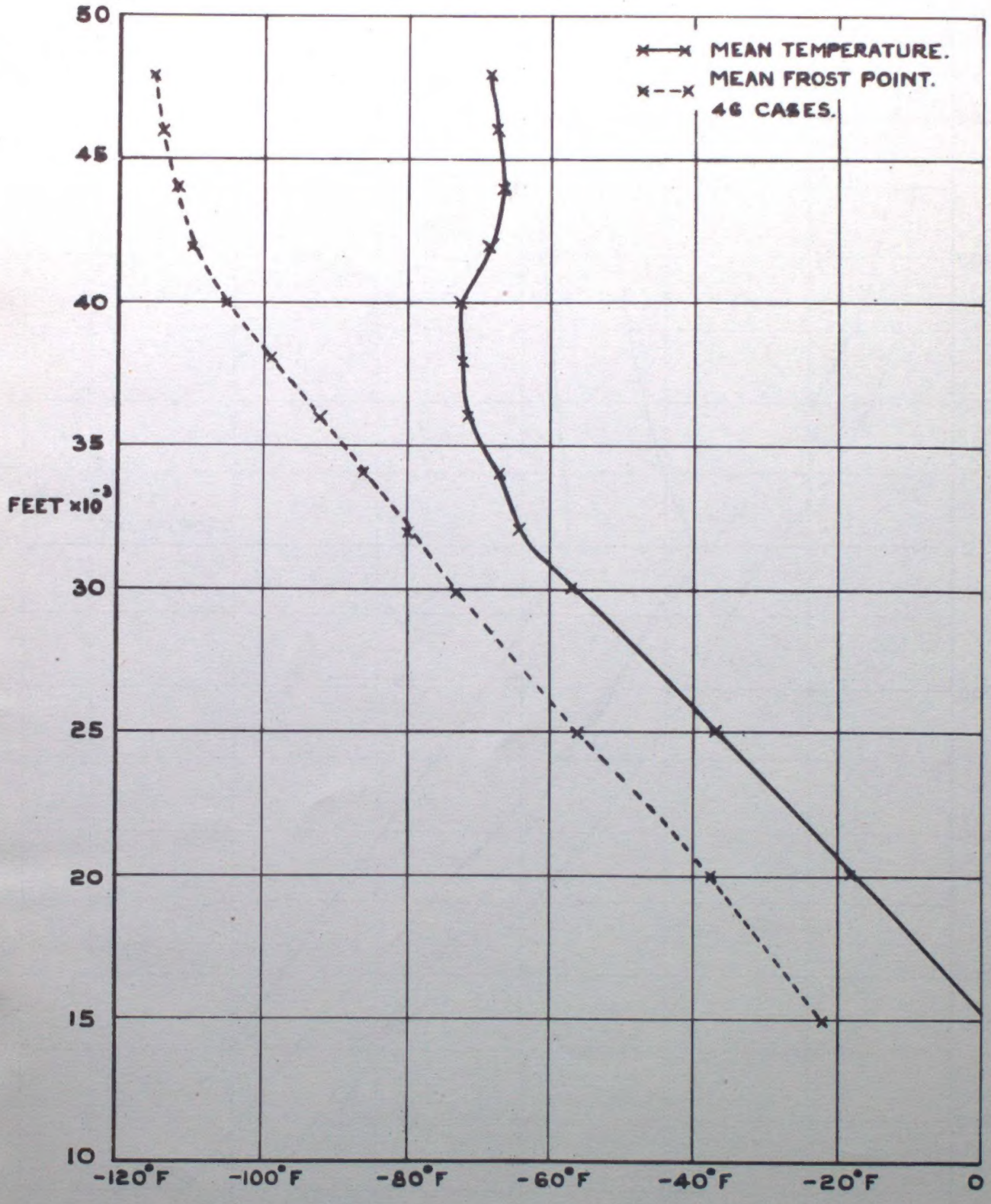

FIG. I. MEAN TEMPERATURE AND FROST POINT 1955.

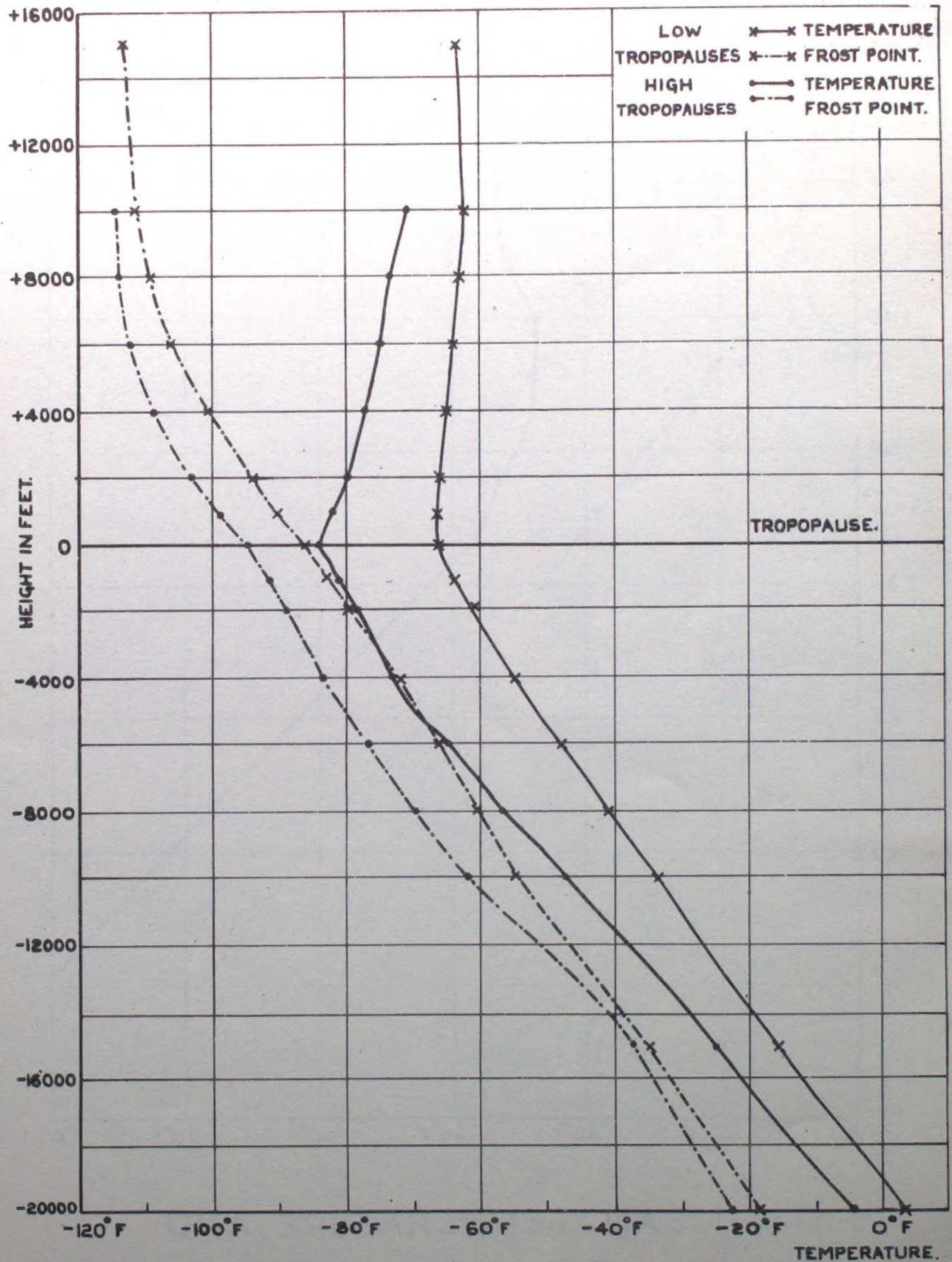

FIG. 2. MEAN TEMPERATURE AND FROST POINT REFERRED TO THE TROPOPAUSE.

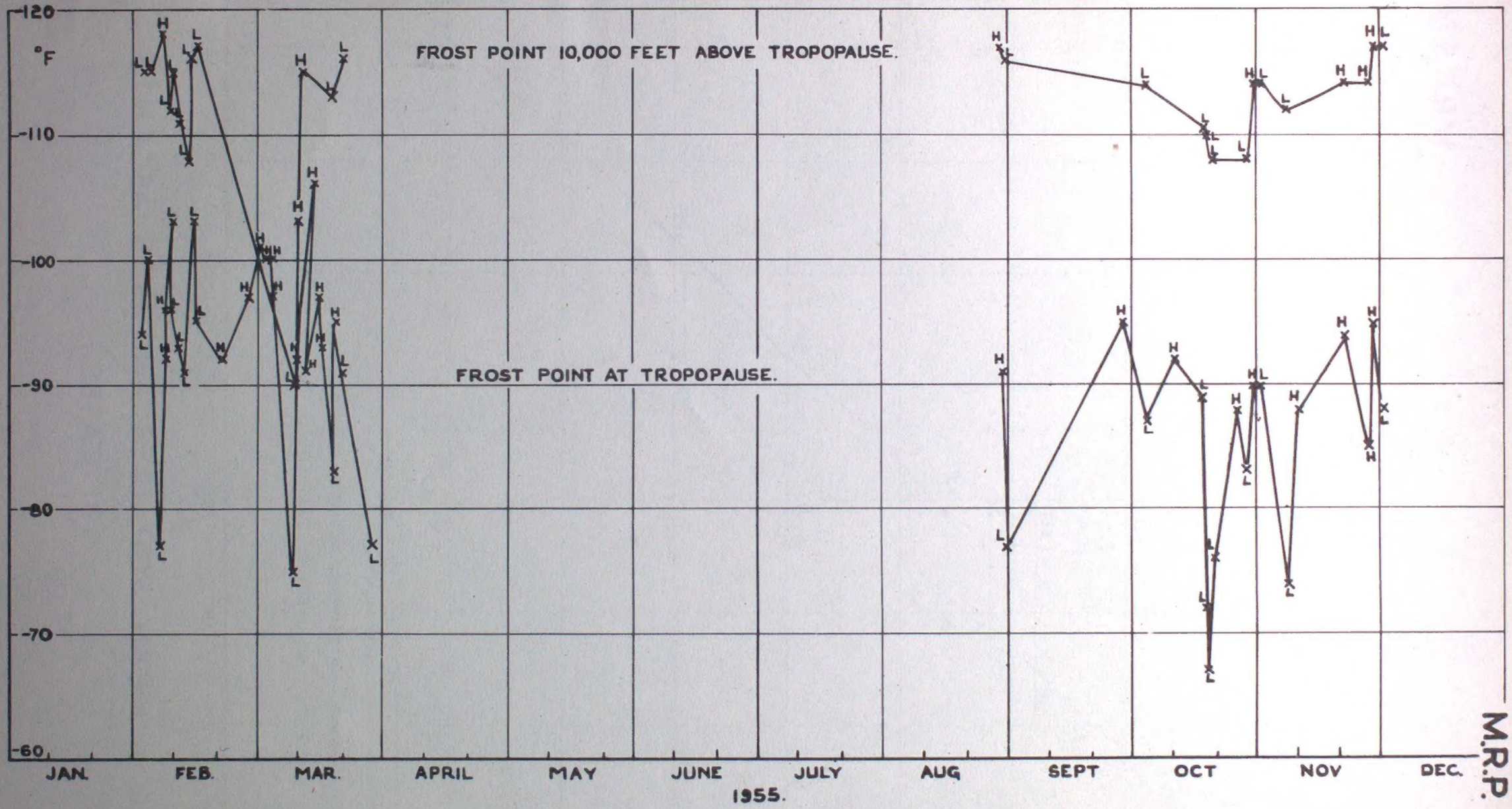

FIG. 3. DAY-TO-DAY VARIATIONS OF FROST POINT

M.R.P. 976.

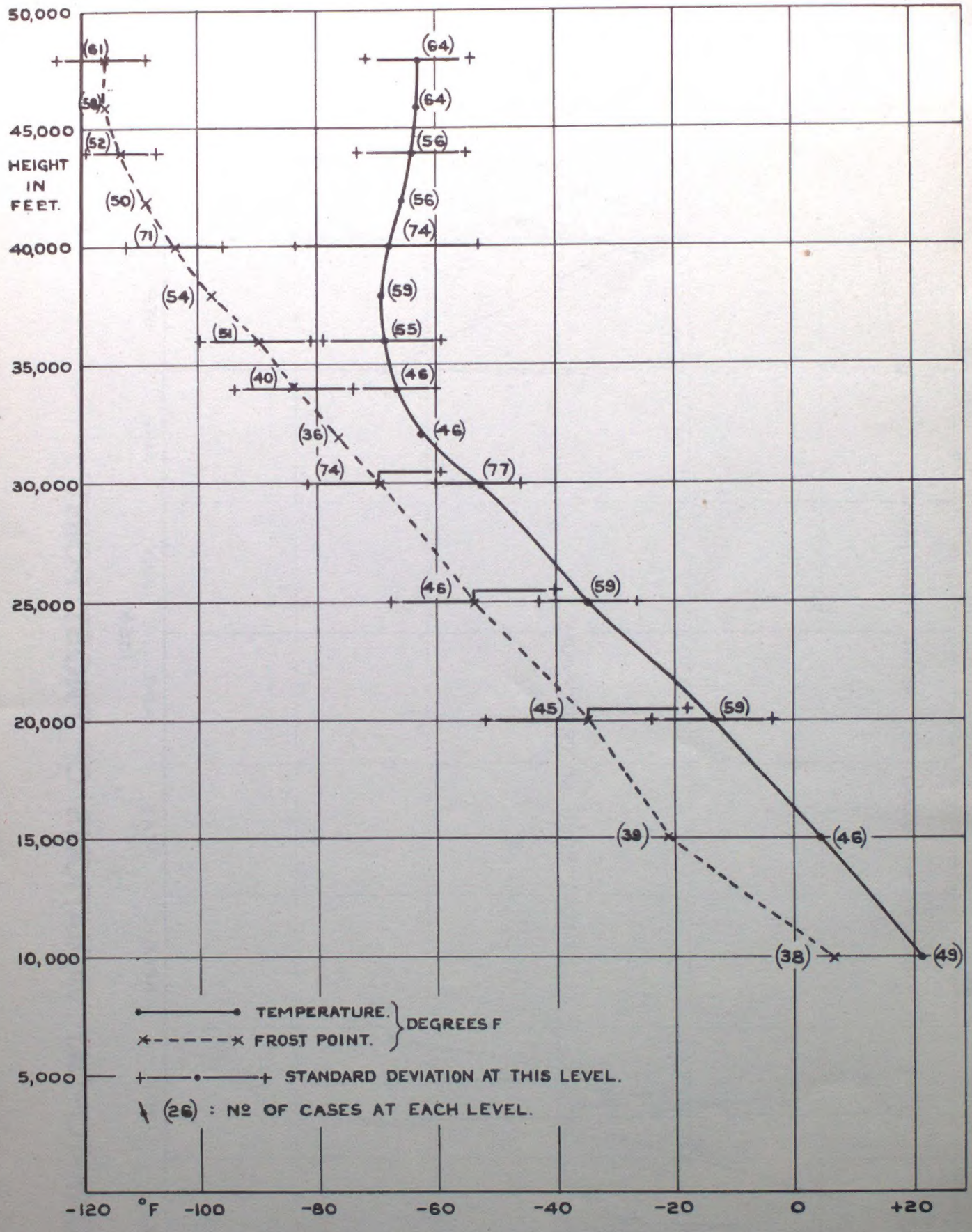

FIG. 4. MEAN FOR 1954 AND 1955 ASCENTS (81 CASES.)

M.R.P. 976.

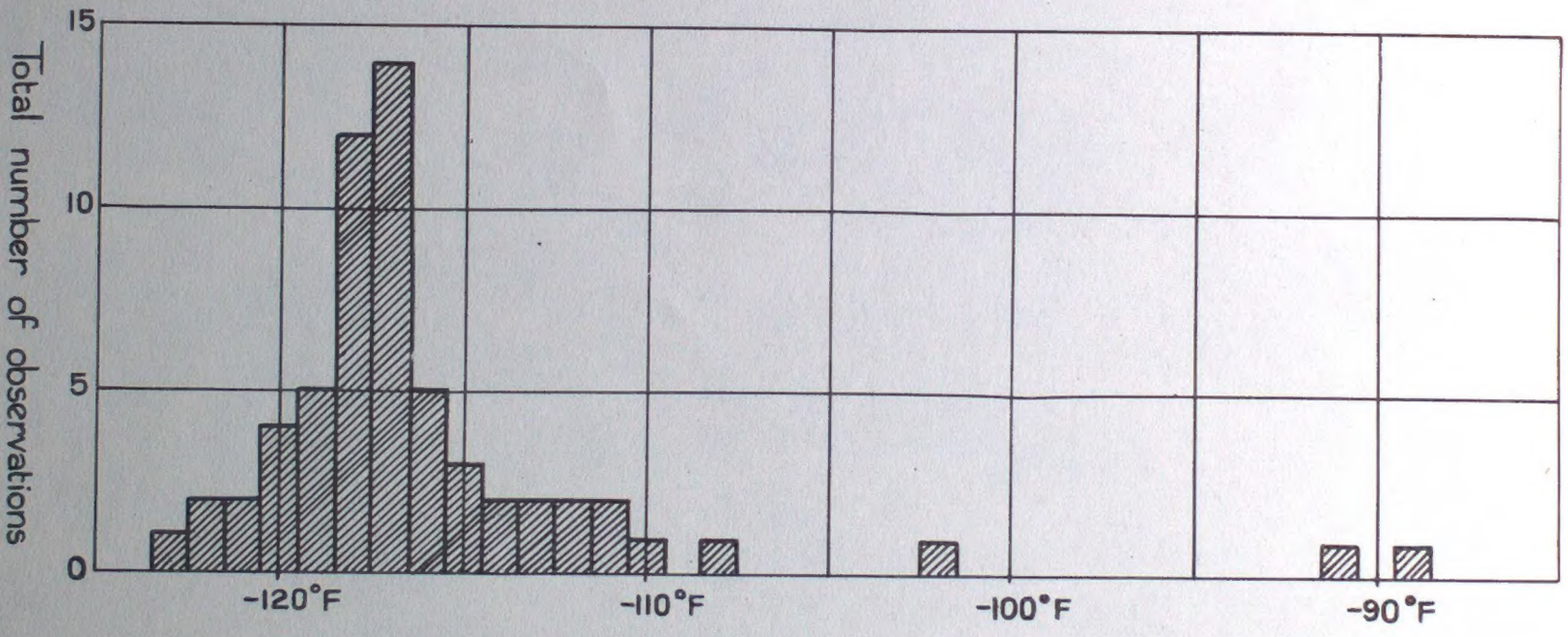

FIG. 5. HISTOGRAM – FROST POINTS AT 48,000 FEET.
(61 CASES)